Decision Applications Division

Research Summaries

Information Integration Technology

n many disciplines, integration of scientific theory and analysis with experimental data, modeling results, and other types of information occurs through some test event or in the mind of a scientist or decision maker. The goal of information integration technology (IIT) is to develop methods for combining and integrating information from diverse sources to produce a traceable, mathematically rigorous assessment of system performance.

For example, to help understand reliability of a complex system, members of D-1's System Ethnography and Qualitative Modeling Team work with statisticians and customers to develop analytical models that allow us to combine system and component reliability estimates and to analyze diverse data sources, including expert judgment, in a way that clients understand.

We have developed a framework of processes and tools to automate much of the modeling effort. The framework is flexible enough so that we can make use of information from a variety of sources, including theoretical models, test data, computer simulations, expertise, and expert judgment. It merges techniques from statistics and probability, graph theory, knowledge acquisition and representation, computer science and simulation, and decision theory. IIT integrates these diverse sources of

information and associated uncertainties to develop full distributions for performance metrics that can aid decision making under uncertainty.

We are applying IIT in collaboration with partners from the weapons community here at the Laboratory, from industry, and from the DoD. For example, in conjunction with the Missile Defense Agency, we developed a predictive reliability model for an upcoming flight.

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Information Integration Technology (III) has a wide spectrum of application areas, from improving the reliability of production processes for diapers to predicting performance of weapons systems.

Genetic Data Analysis

ur genetic data analysis research involves management and analysis of information about biological systems. An example is Amplified Fragment Length Polymorphisms (AFLP) Analysis. Given an inventory of fragments of given lengths, because of a specific cutting routine, it is possible to make comparisons through "fingerprints," that is, reduced parameter data sets specific to each organism.

In collaboration with scientists from B Division, we create models of the data, and then perform a statistical/computer-based analysis of AFLP data. This analysis allows us to identify and classify biological organisms of interest with regard to national security issues.

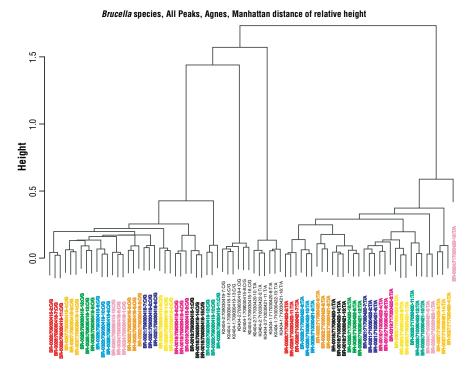
AFLP analysis has been used to classify and identify certain organisms that have been in the news recently, including strains of *Bacillus anthracis* (the bacterium that causes anthrax). Other issues we are addressing include using replicates (they are sometimes not used because of excessive analysis time), the incorporation of uncertainty in comparisons/decisions, and data integration (e.g., how to combine information from controlled experiments with "real world" data from the field, perhaps from intelligence sources).

Applications include rapid identification of organisms and pathogens, identification of geographic soil locations, classification of ecological microclimates, development of "background" soil and air microorganism content, and early warning systems/surveillance for biological threat agents.

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Comparison of replicates from two different amplified fragment-length polymorphism (AFLP) primer pair profiles. The clustering of the replicates shows that these data analysis techniques for AFLP profiles might be used to identify unknowns.

Computational Statistics

ADAS, (the shorthand name of the Yet Another Data Analysis System) is a software system written in Java for MCMC analysis of statistical models. It is intended to be extensible to handle new models that researchers devise and to make it easy to implement these models. It emphasizes the use of Metropolis steps, relieving the user of the responsibility of calculating full conditional distributions. YADAS contains a versatile library for expressing relationships between parameters, as well as a library for proposing parameter updates that improve the mixing properties of the chain.

YADAS has several features that will appeal to statistical researchers. It enables the specification of most models without writing a great deal of new code and allows users to update the parameters in their MCMC algorithms in arbitrary ways. It also offers an easy method to propose Metropolis-Hastings moves in arbitrary directions and powerful and intuitive ways to improve convergence of difficult MCMC algorithms.

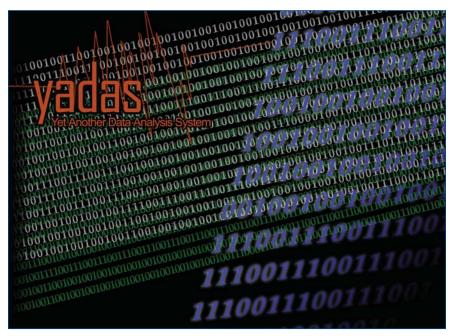
The source code for YADAS is openly available, and researchers are encouraged to modify it for their own use. The program is receiving widespread use within D-1 and has been acknowledged as pivotal in solving several very time-consuming problems

D-1 statisticians, in collaboration with weapons scientists at the Laboratory, have used YADAS to analyze and estimate the reliability of stockpile components. It has also been used to model and analyze performance of a complex system for with a mixture of information, some at the system level, some at component level, and some at subcomponent level. YADAS is especially well-suited for analysis of such types of hierarchical models.

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YADAS contains a versatile library for expressing relationships between parameters, as well as a library for proposing parameter updates that improve the mixing properties of the chain.

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Uncertainty Quantification

he Laboratory's certification efforts supported by developing methodologies to quantify the uncertainty in all aspects of performance of the stockpile. We provide this support through modeling and statistical analysis of physical data, and also through computer model evaluation.

With computer models, we are concerned with how far apart the real outcome and predicted outcome are likely to be at a specific prediction point in light of evidence at other, specific data points. The real and predicted outcomes can be expected to differ for several reasons, e.g., uncertainty resulting from model specification (it may be too far removed from reality) or inputs (data used may not adequately characterize actual conditions in the physical world).

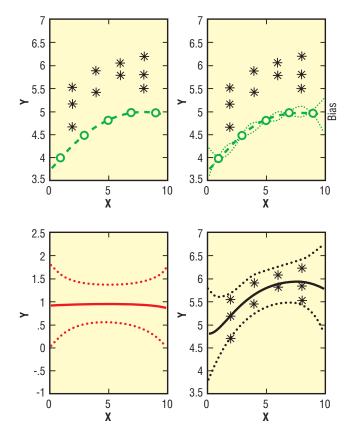
D-1 is collaborating with weapon physicists on several efforts to integrate and utilize all available information and relevant data in environments where data is sparse, expensive, and, in some cases, impossible to obtain. Methods developed and applied on these projects include Bayesian (data combining) methods, analysis of expert judgment, linear and nonlinear modeling, multivariate analysis, and analysis of variance components.

We have applied these methods and tools to help answer questions in a variety of areas, from sampling issues that arise in core surveillance to resolution of significant findings.

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(Upper left) Observed field data (black circles) and simulation output (green dots) taken at various configurations x. (Upper right) An interpolative model for the simulator is constructed to estimate simulation output at untried values of x, along with its uncertainty. (Lower left) Estimated discrepancy term and its uncertainty. (Lower right) Predictions for new observations are given by the sum of the simulator and the discrepancy.

Improving the Reliability of Large-Scale Industrial Manufacturing Processes

n collaboration with Procter & Gamble (P&G), D-1 staff members have developed a statistical model to evaluate the reliability/availability of alternative process configurations. PowerFactoRE is a suite of reliability engineering tools for optimizing the manufacturing process. It is a comprehensive methodology and an integrated suite of reliability engineering tools that introduces a new way of thinking about the manufacturing process.

PowerFactoRE received an R&D 100 Award in 2003. The model is developed in such a way that a genetic algorithm can be used to identify those processes having high reliability/availability.

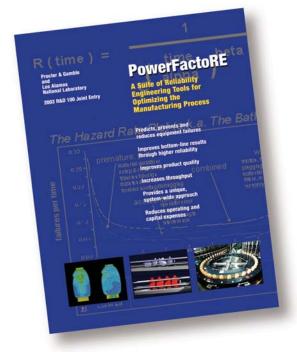
PowerFactoRE comprises a unique set of proven methods, statistical and analytical tools, simulation software, procedures, and training that enables manufacturing line managers to understand reliability losses and to correct seemingly isolated defects in the manufacturing process. It gathers and analyzes production data; fits the data with accurate statistical distributions to build a simulation of the system; and validates the system model.

It allows a manufacturer to improve the current system or to evaluate a completely new configuration. This methodology can be applied across a wide range of businesses to increase productivity and production and to guide capital investments. It is currently being used in more than 200 plants worldwide, and P&G has saved over one billion dollars since implementing PowerFactoRE.

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PowerFactoRE is a unique set of tools that assists manufacturing line managers in assessing reliability losses and in correcting isolated defects.

It earned a 2003 R&D 100 Award.

Statistical Population Bounding

ften, we are not interested in confidence intervals on means, but in bounds on quantiles of distributions. The basic population bounding problem is to determine bounds that contain a desired fraction of the population. In other words, whereas confidence limits bound the mean with a specified level of confidence, and prediction limits bound individual predicted points, tolerance bounds contain a specified proportion of a population with a desired confidence. Collaborating with physical scientists, we create statistical models to study the behavior of material characteristics.

In extensions from the basic problem, we consider distributions as they age over time, multiple populations, assessment of measurement processes, and bounds on probabilities.

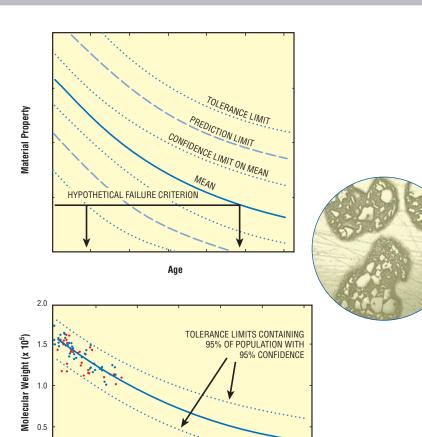
Using these techniques, we have studied the behavior of plutonium over time by designing and analyzing experiments to collect measurements of samples of aged plutonium. We have also modeled and provided uncertainty bounds for age-related material characteristics (such as molecular weight) of the polymer binder in high explosives.

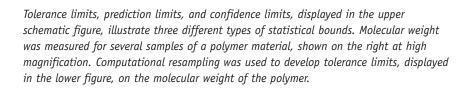
Other application areas include analysis of historical data on engineering components to predict and bound behavior of components over time; evaluating the reliability of canisters for use

in long-term storage of radioactive waste with particular interest in degradation associated with internal pressure build-up with time; analysis of glove box fail-ure data to understand glove deterioration and age-related failures; and models to understand environmental exposure, material properties, measurement and production system variation, and non-destructive measurement techniques.

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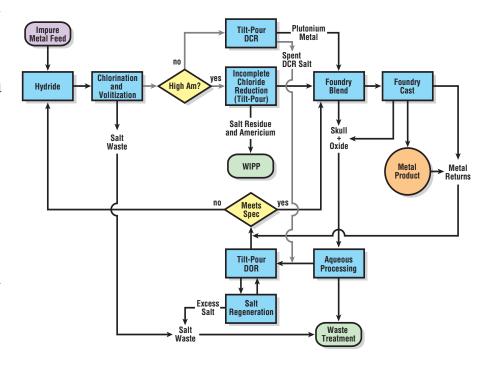
Modern Pit Facility Manufacturing Systems Modeling and Analysis

his Modern Pit Facility (MPF) Manufacturing Systems Modeling & Analysis project uses a combination of modeling, simulation and, analytical tools to perform a systematic, detailed analysis of several types of manufacturing systems including factories, recovery/refining operations, and assembly operations. The project first deploys a data acquisition team to obtain detailed operational, layout, and unit process information. This part of the analysis is usually the most valuable to anyone interested is determining how a manufacturing system is functioning in terms of efficiency, resource utilization, and management capability.

The information gleaned from the data acquisition process is then incorporated into a system modeling/simulation tool called ProMoS, and the team runs the simulation to determine obvious bottlenecks and other nascent system features and to validate the tool and data. Necessary adjustments are made to the tool and the team submits any requests for additional data. Both the modifications to the database and/or tool configuration and the additional data requests represent the second most important aspect of the entire process. After completing the modifications and incorporating the additional data, the

team runs the simulations again for data verification and to determine the completeness of the database and manufacturing features of the system under investigation. This modification/database-refinement process is repeated until we attain the level of precision necessary to complete the systems analysis to the satisfaction of the customer.

Once the model is appropriately modified and the data is refined, the model performs the required simulations for record to establish the baseline. A baseline is established and validated, then the model is run in a variety of customer/client-provided scenarios to provide an operating envelope for the manufacturing system under study. The team uses Access, Excel, and PROOF (a visualization tool) to create a detailed analysis of these scenarios and to provide datarich numerical and graphical representations of overall system performance under the scenario conditions. As a result, a factory can be operated virtually to determine if green-field newbuilds, modifications, expansions, or transformations can be economically or efficiently completed and operated as designed. Additionally, the analysis may be performed to "optimize" an existing system to increase resource utilization or maximize profit.



Metal preparation/purification flowsheet for the Modern Pit Facility (MPF).

The team conducts a model-based analysis of complex manufacturing systems—in particular, small-lot manufacturing of high-reliability components or assemblies. The results of the analyses are used to complete simulations of factory performance during the design phase to reduce design and build costs

and to increase factory productivity and robustness. A factory can be designed to operate in any specified optimal mode.

We developed models that provide comparisons between the different technologies for the MPF program and to establish data to guide technology development. The potential impact of a given technology can be tested in the manufacturing environment (assuming best estimated performance criteria) to determine the productivity, cost, or safety performance of the modeled technology. This approach determines which projects have high-impact potential and directs the technology development resources to those projects.

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Pit Manufacturing Capability Program

nder the direction of the NNSA the DOE laboratories and operations sites are re-establishing pit manufacturing capability to assure United States' readiness to manufacture war reserve pits. D-2 manages the LANL Pit Manufacturing Capability Program. In addition to the W88 Manufacturing and Certification Program at the Laboratory, the Pit Manufacturing Capability Program will reacquire and maintain a modern capability to manufacture all pits within the enduring stockpile while supporting other NNSA programs.

Updated manufacturing processes are a critical factor in assuring U.S. readiness and capability to manufacture pits. This team identifies, develops, and deploys new technologies that provide the robust, flexible, cost-effective pit manufacturing capabilities needed to sustain U.S. pit manufacturing capabilities. The manufacturing process will span many decades and is expected to encounter numerous changes in requirements and available technologies during that time. The team continually looks forward to emerging technologies, assesses them, and selects specific technologies for proof of concept and continued development.

Integrated technology planning, decision making, and management are generally applied when several interrelated technologies are going to be combined

into systems where both requirementsdriven technology development and optimization analysis are important.

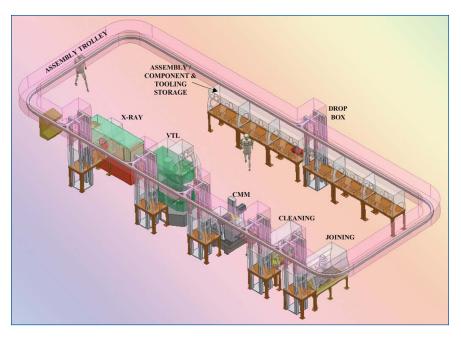
The team has realized several recent accomplishments:

In conjunction with NNSA and the DOE laboratories and sites, they completed a technology integration strategy that defines a national approach to pit technology development.

They organized and now lead the Process Technology Development Board that integrates Laboratory weapons manufacturing process development. They established an optimized manufacturing baseline and defined the process priorities and competing technologies.

Additionally, they completed the Pit Manufacturing Technology
Implementation Integrated Plan for NNSA that integrates the complex-wide development program and initiated and procured equipment for the Laboratory's technology development efforts that support pit manufacturing.

The team collaborates with colleagues at NNSA, Lawrence Livermore National Laboratory, Sandia National Laboratory, Savannah River Site, Kansas City Site, Y12 Site, and Laboratory divisions D, NMT, ESA, X, and MST.



Proposed advanced pit fabrication model.

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Complex Manufacturing Systems Modeling and Analysis

he Complex Manufacturing Systems Modeling and Analysis project uses a combination of modeling, simulation, and analysis tools to perform a systematic, detailed analysis of manufacturing systems. It first deploys a data acquisition team to obtain detailed operational, layout and unit process information. The information is then incorporated into the ProMoS simulation tool, and the system is then simulated to determine obvious bottlenecks and other nascent system features to validate the tool and data. Adjustments are then made to the data base and/or tool configuration and the simulation is then run for record.

Once a baseline is established and validated, the model is run in a variety of customer/client provided scenarios to provide an operating envelope for the manufacturing system under study. The detailed analyses of these scenarios are performed using Access, Excel, and PROOF to provide data-rich numerical and graphical representations of overall system performance under the scenario conditions. As a result, the factory can be operated virtually to determine if green-field new-builds, modifications, expansions, or transformations can be economically or efficiently completed and operated as designed.

The team conducts model-based analysis of complex manufacturing

systems, in particular, small-lot manufacturing of high-reliability components or assemblies. The team used the completed factory performance simulations during the design phase to reduce design and build costs and to increase factory productivity and robustness. A factory can be designed to operate in any specified optimal mode.

Models were developed that provide information for the MPF program and establish data to guide technology development. The potential impact of a given technology can be tested in the manufacturing environment (assuming best estimated performance criteria) to determine the productivity, cost, or safety performance of the modeled technology. The results can be used to determine the projects with high-impact potential and then direct technology development resources towards those particular projects.

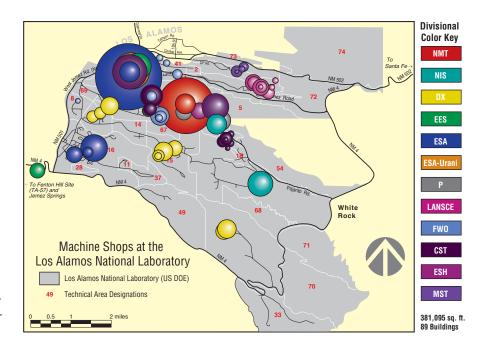
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Model-based analysis of complex manufacturing systems, including processes at various locations, helps optimize manufacturing processes.

Nuclear Planning and Analysis

ntegrated Nuclear Planning (INP) is a concept born in part out of the Chemistry Metallurgy Research (CMR) Upgrades Project and in support of the CMR Replacement Project. Several projects at Los Alamos will be working in the Pajarito corridor to provide or support nuclear materials operations. These projects will benefit considerably from an integrated site-wide planning approach that transcends independent organizations and programs.

Integrated planning should minimize gaps and overlaps of capabilities between various projects and provide a cost-efficient framework for addressing infrastructure needs, including office space, cold work space, security, roads and parking lots, and utilities. The focus of integrated nuclear planning is to initiate workshops that bring Laboratory and DOE personnel together to address issues and establish consensus/consent on those issues, and to direct Laboratory personnel regarding further studies, such as establishing mission requirements, responding to required action elements, prioritizing elements for implementation, and defining individual project scope and schedule.

Integrated Nuclear Planning is generally applied when several interrelated projects are going to be executed, such that interference and optimization analyses are important.

The INP team has organized and led six joint DOE/Los Alamos workshops to date:

Workshop 1 was held at DOE/AL on April 18, 2001. The focus was on establishing the Laboratory-supported plutonium-related mission set for the foreseeable future.

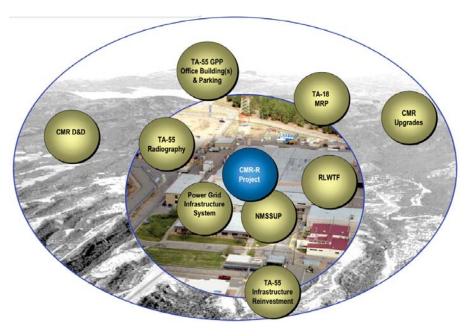
Workshop 2 was held at DOE/Albuquerque (AL) on July 10–11, 2001. The focus of the first day was the TA-18 Relocation Project. The second day focused on establishing the operations to be housed in CMRR and a first estimate of space requirements.

Workshop 3 was held at DOE/AL July 23–24, 2002. This workshop included a variety of topics including the CMRR, TA-55 facility issues, radioactive liquid waste treatment facility (RLWTF), and Los Alamos space consolidation efforts.

Workshop 4 was held at D0E/HQ October 8, 2002. The focus was a revalidation of the mission set and customer base for TA-18 operations.

Workshop 5 was held at DOE/AL June 9–10, 2003. The focus was on the selection of the preliminary CMRR layout and options revalidation.

Workshop 6 was held at DOE/AL on August 19–20, 2003. The focus was INP-related project interface issues and the status of the working teams looking at safeguards and security, large vessels, and storage.



A conceptual view of the projects to be focused on by the Integrated Nuclear Planning team. Currently, the central project is the CMR Replacement Project.

The next workshop is being planned for Spring 2004.

Collaborators on this project are DOE, the Laboratory's C, NMT, S, PM, and NIS Divisions, and the ADO office.

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Biological Countermeasures Programs

he Biological Aerosol Sentry and Information System (BASIS) program has developed integrated systems for countering aerosolized bioterrorist releases. Our detect-to-treat technology includes air-sampling hardware, controlling software, and high-confidence DNA-based analysis to rapidly detect, time-and-place pinpoint, and species/strain-characterize aerosolized bioagents.

The visible "front end" component of BASIS is a network of strategically deployed air samplers in and around cities, airline terminals, bridges, etc. Software for this program has been developed to keep tabs on air-sampling operations. BASIS operators must adjust the air samplers' parameters from time to time, so each sampler communicates with the operator by laptop computers running the BASIS Command and Control software, through coaxial cable, radio frequency, or cellular modem. The software allows the operators to remotely monitor and adjust all critical parameters for the samplers. For rapid recognition, these parameters are displayed both numerically and graphically. The BASIS architecture was adapted in early 2002 to support the nationwide deployment of BioWatch, a DHS-sponsored program to detect a bioaerosol release in many U.S. cities.

The Incident Characterization Action Plan (ICAP) is an effort to develop a template for the early stages of the consequence management operation that would be initiated by indications from BioWatch that a bioterrorism incident may have occurred. Specifically, it focuses on operations during the first few days after a positive detection, when it will be essential to characterize the event as quickly and completely as possible. The deliverable of this effort will be a "template" that will be provided to all BioWatch cities.

The BioNet program is a cooperative program between the DHS and the DTRA. This program will integrate both civilian and military capabilities for detecting and managing the consequences of biological events, including bioterrorist attacks. BioNet will leverage DTRA and DHS consequence management capabilities to support DHS's science and technology objectives and DTRA's mission. We will also optimize systems and concepts of operations (ConOps), develop consequence management tools and ConOps, operationally evaluate the next generation of aerosol monitoring technologies, expand high-throughput sample processing capabilities, and develop system optimization models.

The BASIS and BioWatch systems are designed for indoor or outdoor deployment in any situation in with a proba-

BASIS provides early warning of airborne biological weapons attacks. Planned for use in civilian settings, BASIS can detect a biological attack within a few hours, early enough to treat exposed victims and limit casualties significantly.

bility or an actual threat of a bioterrorist attack. Currently, the ongoing BioWatch deployment protects a significant number of major American cities, using simplified versions of the BASIS distributed sampling units, deployed in concert with local air quality sampling activities and analyzing filters through laboratories that are part of the Centers for Disease Control and Prevention's (CDC) Laboratory Response Network. The

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deployment is designed to guard against large-scale urban attacks. By deploying a smaller, more-portable air sampler and using the testing laboratories affiliated with the CDC to perform DNA-based analysis, the DHS has quickly pressed the BASIS technology into service. The BASIS team continues its research and development work, seeking to improve all aspects of system performance.

An ICAP manual will be developed to assist the BioWatch cities in establishing a situational awareness team that will direct and implement the ICAP template. This manual will include recommendations regarding actions and time lines, needed information products, available tools and resources, notifications and communications, and membership.

There are significant variations in the emergency response structures and approaches in the BioWatch cities. The ICAP manual will serve as a "starting point" for the development of specific plans suitable for the unique characteristics of an individual locality. In addition to providing guidance to state and local agencies for their own operations, it will specify how these can mesh with federal response operations under the National Incident Management System (NIMS), especially those that are controlled by DHS.

The BASIS team earned an R&D 100 Award in 2003. This program also received a Laboratory large-team Distinguished Performance Award. In 2002, BASIS was deployed at the Winter Olympics in Salt Lake City and in New York City for the anniversary commemoration of September 11th.

D-3 collaborates with Lawrence Livermore National Laboratory, Rupperecht and Patashnick Co. Inc., the U.S. Environmental Protection Agency, the Centers for Disease Control and Prevention, local air quality agencies, and the Laboratory's P-24, ISR-4, and S-10 groups in these efforts.

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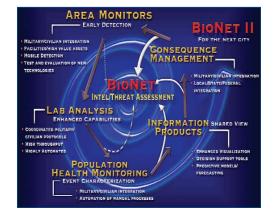
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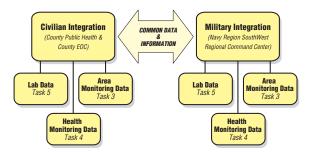
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(Upper) Screen shot of BASIS operations console. (Middle) BioNet flow chart. (Lower) The primary goal of BioNet is to make the civilian (BioWatch) and the military (Guardian) programs interoperable.





Maritime Study

he Maritime Surveillance System Study is a systems-based assessment of alternative technologies and surveillance strategies to detect nuclear weapons smuggling, radiological dispersion devices (rdds), and special nuclear materials in shipping containers. It addresses the smuggling opportunities afforded by the seven million intentionally opaque containers imported through U.S. ports annually that are a potential threat to homeland security.

The study consists of six major elements: (1) a physics-and engineeringbased assessment of the available and near-term sensor technologies for detecting nuclear materials hidden in shipping containers, (2) an economic analysis of the impact of surveillance operations on the maritime transportation system, (3) an assessment of the available data on the maritime shipping system, collecting data, and maintaining a database, (4) a high-fidelity simulation of shipping terminal operations, (5) a systems model that evaluates surveillance strategies, and (6) an analytic effort to create, compare, and optimize alternative surveillance strategies.

In addition to the direct application of detecting nuclear weapons, rdds, and nuclear materials in shipping containers, the study developed an approach, methodology, architecture, and tool-set for use in other surveillance applications. The analysis extends directly to rail, road, and airfreight imports. The study methodology also would apply to other targets, such as biological, chemical, or conventional weaponry, if the appropriate sensor technologies can be identified and assessed.

The study has produced a comprehensive assessment of passive radiation sensor technology, radiographic imaging technology, and active irradiation technologies for detecting concealed actinides and other radioisotopes. In addition, the study has developed a methodology to assess the performance of information-based methods (e.g., shipping manifest assessment). A highfidelity, agent-based simulation of a representative shipping terminal has been implemented and validated and is used to perform million-container numerical experiments to examine the impact of surveillance operations on the terminal. The assemblage of data from many diverse aspects of the maritime transportation system is a unique asset. We have developed a conceptually simple yet powerful architecture for representing surveillance systems with multiple sensor types in a way that allows comparison and optimization of surveillance strategies.

The study has participants from throughout D Division and the Laboratory's P and N Divisions. Outside the Lab,





D Division is actively involved in a maritime surveillance study that analyzes potential vulnerabilities of commercial shipping. With the system shown in the upper photo, a large U-shaped structure with a linear accelerator on one side and x-ray detectors on the other can be driven over a cargo container to produce an x-ray image. The resulting image shows neutron emissions, which are a signature of nuclear material.

contributors to the study include U.S. Customs and Border Protection Agency (both operations and intelligence), U.S. Coast Guard, the U.S. Merchant Marine Academy, Lawrence Livermore National Laboratory, Sandia National Laboratory, Pacific Northwest National Laboratory, The Yusen Terminals, Inc. terminal at the Port of Los Angeles, the Maryland Port Authority, the University of Maryland, and the University of Michigan.

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Unconventional Nuclear Warfare Defense

his Unconventional Nuclear
Warfare Defense (UNWD) program
involves the integration of a number of unattended sensors and cameras
with communication links and displays
for potential use in detecting unauthorized movement of radioactive materials.
It also includes sensor testing, communication network design, data format
development, and installation and
implementation issues. The UNWD program is a collaborative effort of multiple
contractors, government agencies, and
national laboratories.

The purpose of this project is to demonstrate the capability for real-time detection and notification of unauthorized radioactive material movement. The system uses a variety of commercially available sensors. The project includes establishing an outdoor test bed for side-by-side testing of radiation sensors with a variety of sources; selecting and installing sensors in a number of outdoor locations; developing a common sensor event reporting format for all sensors; linking the sensors to a central reporting station using a combination of radio frequency (RF), fiber-optic, and copper wire communications links; and selecting cameras and lighting to provide still images and live video of any event triggering any of the sensors. The sensor data and alarm reporting are displayed in real-time in the command center, resulting in immediate notification of response forces and are logged for further analysis. Representative systems have been installed in several operational facilities.

The team used quickly deployable, existing technology from both commercial and government resources to provide detection and reporting capabilities for civilian and military applications, including personnel and vehicle-entry control points to protected facilities. The equipment provides detection and alerting capabilities to on- and off-site security forces and should be employed in concert with existing security policies, procedures, and equipment.

Over the duration of the project, the system design has evolved to include nuclear radiation detection elements, distributed data communications, unambiguous alerting, provisions for both primary (gross) and secondary (detailed) inspection procedures and equipment, documentation of suspect activities (both visual and radiological), provisions for deployment in high- and low-traffic situations, and multilevel monitoring capability. The system includes data and video transmission through hardwire and non-hardwire RF communication.

The system is designed to allow existing security forces to detect, assess (with video snapshots of vehicles), and potentially track unconventional nuclear

weapons, not to replace personnel. Generally, the deployment of this system does not generate additional security forces posts, but acts as a force multiplier by optimizing security forces employment and capability. The system can help the security forces commander to focus forces for the interception and engagement of an unconventional nuclear weapon threat and reduce or eliminate the need to disperse security forces in a detection role. We have installed, tested, and demonstrated the system at four military installations in the U.S., and we are continuing to monitor at some installations.

Lawrence Livermore National Laboratory, Sandia National Laboratory, Northrup Grumman, ARA, U.S. Army, U.S. Navy, U.S. Air Force, U.S. Marines, and DTRA collaborated with the D-3 team on this project.

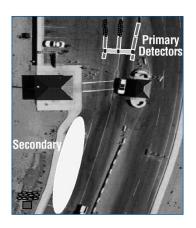
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Portal monitors such as those shown above are specialized radiation sensors that are optimized for detecting radiation from nuclear materials at pedestrian or vehicle choke points. Lower photo is an overhead view.

Graphical Integrated Aggregated Control (GIAC) Program

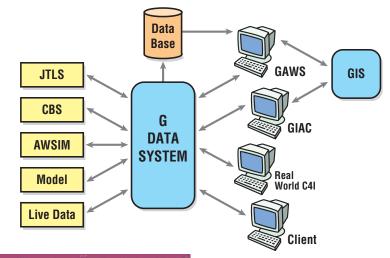
he Graphical Integrated
Aggregated Control (GIAC)
Program is a perfect example of
computer graphics, distributed computing, system configurations and software
engineering being used in one complete
project. GIAC is a software system comprising two components: a graphical
user interface (GUI) and Genis Data
System (GDS), a distributed data system.

GIAC has over 500,000 lines of custom C and X-Motif code. GIAC's main function is to use computer graphics to display an electronic battlefield generation, training simulations, and war games, as well as provide input for simulation objects in a distributed environment—and do it fast (real time, or preferably a 4:1 ratio). GIAC also provides terrain analysis and features including line-of-sight (LOS) calculations, shaded relief mapping, radar echo analysis, terrain profiling, and National Imagery and Mapping Agency (NIMA) image map displays. LOS calculations are done in a distributed manner. GDS allows exercises to be configured over a LAN, or WAN, locally or worldwide. Distribution is accomplished with network programming using a socket application programming interface (api) written by GIAC team members in a point-to-point scheme (TCP/IP). Both software components are a complex code using well-known and custom-written, modified algorithms, and data structures

to obtain the maximum performance and scalability/flexibility possible. GIAC is able to handle the distribution and interactions of over 100,000 simulation objects. The software can function on multiple hardware platforms, including HP, SPARC, and Intel, under those systems' native operating system, as well as Linux.

Every Military Simulation Center in the U.S. and NATO could use GIAC. The GIAC software is used around the clock for valuable training and mission rehearsals and was used to help plan the Kosovo air campaign. Major uses during the past year have been for homeland defense, the Millennium Challenge 02 Experiment, the Air Force's Distributed Mission Training, and many Joint Task Force-level training exercises.

Specifically for Millennium Challenge 02 (MCO2), GIAC was modified to show all the model entities in the MCO2 Federation minus single infantrymen in a White Cell (ground truth) mode. GIAC was also used as a debugging tool for the federation. GIAC was the main command and control (C2) control for air warfare simulation (AWSIM) object in both perceived and ground truth modes. GIAC allowed AWSIM operators to target federation objects and provided a mission history for mission reports (MIS-REPS) and battle damage assessment (BDA) reports.





(Above) Graphical Integrated Aggregated Control (GIAC) High-Level Architecture. (Left) Screen view of the graphical interface during one of the operational aames.

GIAC performed flawlessly while supporting "white team" (ground truth) operations during Millennium Challenge 2002, the largest military experiment in history. The team also received a LANL Distinguished Performance Award for small teams in 2001.

We collaborated with U.S. Joint Forces Command, U.S. Air Force, Warrior Preparation Center, Raytheon, and the Laboratory's ISR-9 group on the GIAC project.

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Institutional Economic Analysis

os Alamos National Laboratory is a large institution that plays an extremely important role in the economic and political life of northern New Mexico and the entire state. The Laboratory continuously encounters opportunities, choices, and alternatives related to this role. Laboratory management requires decision support and analyses to help select among alternatives, examine the consequences and implications of decisions and activities. and generally to sort good ideas from not-so-desirable ones.

Many institutions the size of the Laboratory have a corporate economics department reporting to high-level management in the organization, frequently to the president or director. Although the Laboratory does not have such an organization, D-4 personnel provide the Laboratory's equivalent of corporate economics information to the Director's Office.

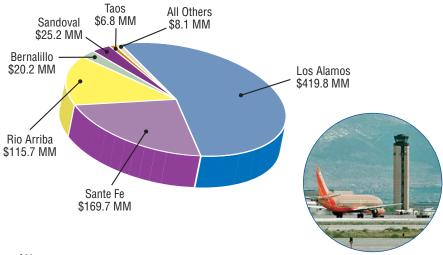
This work involves D-4 teams in a wide variety of decisions and analyses relating to the Laboratory's internal and external activities. One important aspect of the D-4 analyses is the analysts' ability to conduct a fully objective and independent analysis and to reach whatever conclusions the data and analyses dictate—the studies are objective and unbiased.

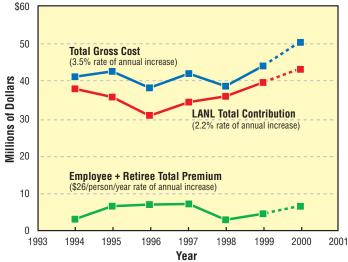
Studies conducted recently on behalf of Laboratory management include:

- ▼ Los Alamos Health Care Study
- Regional Airport Study
- ▼ Diamond Drive Traffic Study
- ▼ Los Alamos Science Complex Construction Alternatives Study
- Gross Receipts Tax Study
- ▼ Various regional economic impact analyses
- V Economic impact analysis of moving 1,000 LANL employees to downtown Los Alamos
- V LANL electric demand forecasting
- ▼ PC Platform Alternatives Study

One example of the importance of these capabilities to the Laboratory is the gross receipts tax study commissioned by the Director's Office in support of the Laboratory lobbyists' efforts at the New Mexico State Legislature. Lobbyists used the study results in briefings and politicians used them in statements in the Tax and Finance Committee hearings. The results indicated the potential negative impact on northern New Mexico if the University of California had to pay gross receipts tax on the project funds it receives from the federal government. Proposed changes in the law would have cost the Laboratory an estimated additional \$60 million that might have come out of project funds.

A main contention of Laboratory employees has been that the Labora-





Decision support and analyses are crucial to examining the implications of the Laboratory's internal and external activities.

tory's health insurance costs are higher than those of other employers. The Los Alamos Health Care Study showed that the Laboratory's health insurance coverage is superior to the health insurance coverage offered by most U.S. employers while at the same time costing employees significantly less. This study was briefed before the Lab's Senior Executive Team and at an All-Manager's Meeting.

Sometimes study conclusions conflict with the management's desired outcomes. In such circumstances, the analyst must be able to support the conclusions with clear analyses and hard data. For example, the Regional Airport Study concluded that a regional airport in the vicinity of Española would not attract viable commercial airline carriers and would not provide the Tri-County region with more proximate airline service. Management personnel were on record publicly supporting the establishment of a regional airport in this location. However, after receiving a briefing on the study and participating in the extended discussions that followed, the issue was tabled.

Generally, these studies are conducted entirely by D-4 staff members; however, the analyses often rely on information and data gleaned from other organizations within the Laboratory and the University. The health insurance study relied upon the Laboratory's Benefits Office as well as personnel from the UC President's Office for information and data on the plan. Group members also met with Blue Cross/Blue Shield person-

nel as well as the University's outside auditors to obtain data and information pertinent to the study. The auditors were briefed on the study results.

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Interdependencies Among Energy Infrastructures

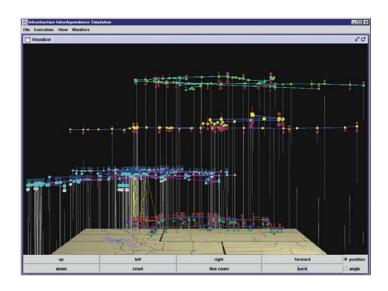
ver the past five years, the Laboratory's analysis of the U.S. electric power grid has expanded into the broader areas of energy generation and transmission infrastructures. We now analyze natural gas pipelines, petroleum liquid networks, telecommunications networks, and the coal infrastructure. The security of the nation is critically dependent upon these infrastructures to provide an appropriate quality of service.

Energy infrastructures typically employ feedback loops among various networks that are critical to delivering the network's products. For example, a gas-fired electric generating plant requires a steady supply of natural gas. The natural gas pipelines may utilize electric-powered compressors to maintain sufficient pressure, setting up an interdependency. Understanding interdependencies is therefore critical to understanding these complex coupled systems. We feel that an inflexible modeling and technology base has hampered prior analysis. Existing modeling and simulation technologies have successfully analyzed single infrastructures but these technologies have severe limitations when it comes to modeling interdependent infrastructures.

The Interdependent Energy Infrastructure Simulation System (IEISS) is currently being applied to a number

of energy infrastructure issues across the country dealing with human-created or natural disasters (see examples below in the figures). The capability is used to address a wide variety of infrastructure questions within states/regions and across the country. It also allows us to identify and understand, in depth, the infrastructure interdependencies during normal operations as well as during disruptions. IEISS provides analysts with the ability to assess the technical, economic, and national security implications of these systems' configurations from an interdependencies perspective. Using the IEISS tools, we can create a detailed analysis and understanding of entire interdependent infrastructures, including their components and couplings, in a manner far beyond what we could previously. We envision a diversity of possible applications for analyses based on IEISS. Our analysis efforts are intended to assist decision makers in the areas of policy analysis, investment and mitigation planning, education and training, vulnerability and criticality assessments, consequence management, and real-time crisis assistance.

Additionally, IEISS can be used as a research tool for investigating fundamental issues related to real-life, nonlinear, coupled, complex networks. Our analyses focus primarily on normal or off-normal conditions arising within



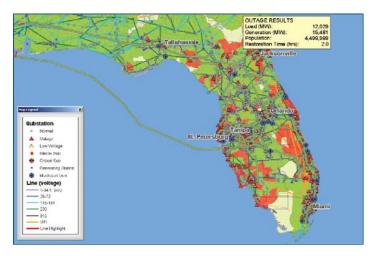


Fig. 1 Network interdependencies identified for the Salt Lake City, Utah, area. Fig. 2 Natural gas-electric power interdependency impacts in the Florida peninsula.

each regional network or within a local network serving one or more sites of interest. Site-specific analysis can also include service and outage area estimates, as well as estimates of outage duration based upon component criticality considerations. Additional attention is often given to an appropriate interpretation of system-level metrics that result in degradations to commercial delivery capability and to varying system conditions throughout a typical year.

Interdependency analysis often includes three components: Regional System Analysis, Local Operational Area Analysis, and On-Site Analysis. These analyses use both quantitative and qualitative processes; with a better opportunity to use quantitative processes the closer the network is analyzed to the site of interest. In electric networks, for example, identification of transmission/subtransmission lines critical for power transfer with adjacent control areas, within the control area, subtransmission system configuration, and generating units available to support local system demand and voltage stability are considered.

Modeling network performance is a fundamental part of the analysis process and is used as a verification tool, to estimate of system performance under adverse operating conditions, for representing infrastructure in a geographic information system format, and for graphic presentations in written reports.

IEISS was used in studies that served as preparation for the 2002 Salt Lake City Olympics. Figure 1 shows an

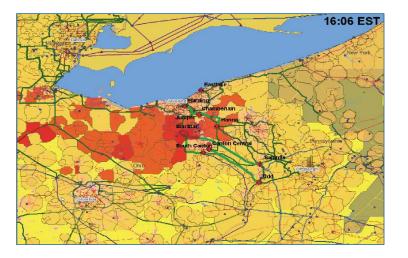
abstract three-dimensional visualization of major energy infrastructure networks (crude oil pipelines, petroleum product pipelines, electric power transmission lines, and natural gas pipelines) overlaid on a map of Utah identifying key Olympic venue sites; the various vertical lines identify interdependencies between the systems. IEISS has also been used to investigate loss of critical natural gas pipelines in Florida, to assess electric component outage sequences during the August 2003 regional electric outage, and to estimate the widespread outage areas caused by Hurricane Isabel in September 2003. Figures 2, 3, and 4 highlight these applications.

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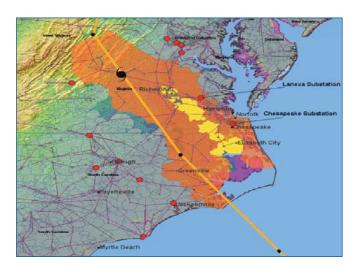


Fig. 3 Regional voltage stress simulation for the August 2003 electric outage. Fig. 4 Estimated wind damage contours for Hurricane Isabel.

Quick Urban and Industrial Complex (QUIC) Dispersion Modeling System

o respond to the threat of a terrorist releasing a chemical or biological (CB) agent in a city, Laboratory and University of Utah researchers have developed a fastresponse urban transport and dispersion modeling system. Fast models are essential for vulnerability studies where many cases must be simulated in a limited amount of time or for emergency response scenarios when an answer is needed quickly. However, the presence of building makes the dispersion of a CB agent released in an urban area difficult to predict. Most emergency response dispersion models currently in use have little or no building "awareness." The Quick Urban and Industrial Complex (QUIC) fast-response urban dispersion modeling system computes the threedimensional wind patterns and dispersion of airborne contaminants around clusters of buildings. The system is comprises a wind model, QUIC-URB; a Lagrangian dispersion model, QUIC-PLUME; and a graphical user interface, QUIC-GUI.

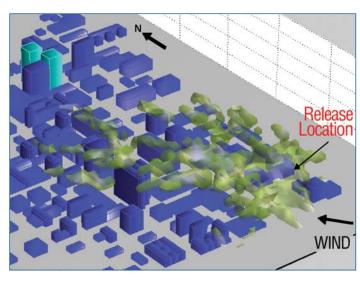
Vulnerability Studies, Training, and Emergency Response

QUIC provides credible models of agent dispersal patterns in an urban environ-

ment, while still achieving very quick turnaround and ease-of-use. It is ideal for planning and assessing many CB agent attack scenarios. It could be used in next-generation training with unscripted tabletop exercises and immediate feedback. Because of its speed, it could be run around the clock at a military base or high-profile target (e.g., D.C. Mall), ingesting local wind measurements in realtime.

We developed the QUIC tool with an easy-to-use graphical user interface that can compute 3-D wind and concentration fields around building complexes in less than a minute. A novel approach for the estimating of turbulent mixing in building wakes was required for good comparisons between model simulations and measurements. The graphical interface permits easy visualization of concentration patterns, agent travel, wind fields, and deposition patterns.

QUIC can also simulate deposition of agents on walls and rooftops and on the ground. Consequently, it can provide guidance for investigators taking "swipes" of surfaces in post-event investigations. Normally, fast-running models can only describe averaged deposition and offer no guidance for the relative importance of streets, walls, roofs, or alternate sides of street canyons that



QUIC-PLUME simulation of CB agent transport and dispersion in downtown Salt Lake City, Utah. The agent cloud is quickly lofted into the air because of the presence of tall buildings.

may be collecting deposited agents. QUIC's deposition details can help the investigations into events and the cleanup in the aftermath of CB events.

Sensor Siting

The QUIC code is also the underlying engine in the QUIC Sensor Siting tool, used for determining the optimal placement of CB agent sensors around building complexes. Early detection of a bioweapon attack—which might go

unnoticed and unpublicized—would allow timely medical intervention that could save hundreds or thousands of lives. Alarms from judiciously placed chemical agent sensors could trigger mitigation strategies such as closing ventilation intakes. Because of high cost and operational logistics, most facilities will only be able to site a handful of CB sensors. The QUIC Sensor Siting tool gives quantitative answers on where to place sensors around a building complex

to maximize the probability of detecting a CB agent attack.

We developed the Sensor Siting tool to produce maps showing the best (and worst) places to put CB agent sensors around building complexes. The maps show the probability of detection of releases of a user-selected, source strength for the conditions of interest.

QUIC fills a significant void between fast, but low-fidelity, conventional plume dispersion models and high-fidelity, but slow, computational fluid dynamics models. The QUIC tool satisfies a critical need in the CB countermeasures arena.

The Laboratory's QUIC team collaborated with the University of Utah,
Oklahoma University, Arizona State
University, and University of California
at Riverside on this project.

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Applied Transportation Studies

nlike traditional static models that can only model transportation and flows at gross levels, the Transportation Analysis Simulation System (TRANSIMS) employs dynamic "bottoms-up," disaggregated modeling techniques. The advantage of the individual carrier/shipment simulation approach is in the level of detail with which the nation's transportation system can be represented—from trucks and goods moving among counties and within regions to national multimodal traffic flows including cross-border trade with Mexico and Canada. This strength can then be exploited for transportation policy and for security and infrastructure investment purposes.

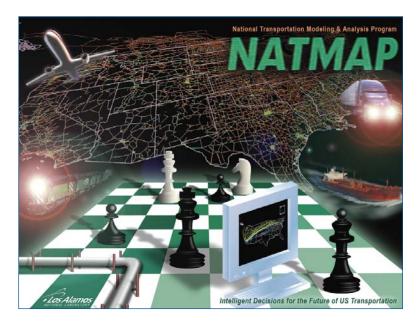
TRANSIMS has been used to model several different situations including:

Traffic Around Los Alamos. The TRANSIMS team evaluated the proposed conversion of Diamond Drive on Laboratory property from four to three lanes. This conversion was intended to address safety issues caused by left turns from Diamond Drive onto two crossing streets and the lane widths being nonstandard. Widening the road was not an option because of the expected high cost. The results were used in planning by Los Alamos County Transportation Division. Further work evaluating traffic security options is being performed.

Coal Over Rail. The Coal over Rail creates a simulation and network to model the movement of critical energy commodities countrywide in support of crisis response planning. Initial efforts will focus on simulating coal shipments from mines in the western U.S. to various power plants in the West and Midwest. Energy disruptions resulting from the loss of various connectors will be observed from the simulation and carried forward to interdependency analyses.

NATMAP-NM (National Transportation Modeling and Analysis Program-New Mexico). The New Mexico Department of Transportation (NM-DOT) is proposing a partnership with the Laboratory to develop and deploy the first statewide, multimodal transportation model in our nation's history. This initiative will adapt these simulation technologies into a tool set for use within metropolitan areas, statewide, state-to-state, and nationally.

The D-4 TRANSIMS team collaborated with the Laboratory's CCS-5 group and FWO Division, the U.S. Department of Transportation, New Mexico Department of Transportation, University of New Mexico, New Mexico State University, New Mexico Tech, and the Metropolitan Planning Organization of Albuquerque.



The National Transportation Modeling and Analysis Program simulates transportation infrastructures at any level of detail—from trucks and goods moving among counties and within regions, to national multimodal traffic flows including cross-border trade with Mexico and Canada.

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Visualization

hether collected from sensors, data is generated synthetically from computer simulations, or from mathematical models, the challenge of exploring and analyzing huge and often complex, high-dimensional data sets is often best met through computer-mediated visualization, or more generally "perceptualization." By adding other sensoria such as sound and touch and lowering the thresholds to interactivity, the human cognitive system can be more closely coupled with the problem domain being studied.

The division has addressed a broad range of problems using visualization techniques. The problems include transportation and population mobility, epidemiology, energy networks and interdependencies, threats and effects of terrorist attacks, military modeling and simulation, ultrascale supercomputing, Internet traffic analysis, and intrusion detection.

Scientific, geographic, statistical, and information visualization tools often play an important role in these tasks. Modern graphics and visualization tools are grounded in the much older arts such as cartography, painting and illustration, graphing and charting, drafting, photography, cinema, and even cartooning. Advances in hardware and software for the entertainment and consumer products industries have made extremely

high-quality, high-speed computer graphics available at very low cost.

The following are some of the projects that team members have contributed to:

The Nuclear Earth Penetrator Project System (NEPPS) included a 3-D interactive visualization of hardened underground targets using Java 3D.

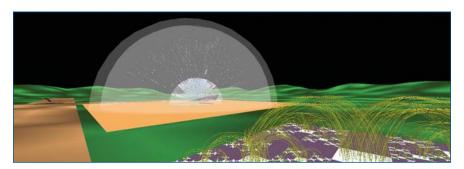
The ShadowJack project applied generative analysis to Future Combat System (FCS) in the Joint Virtual Battle Laboratory (JVB) for DoD, resulting in an automated exploration of the simulation space of the FCS with visualization of the simulation.

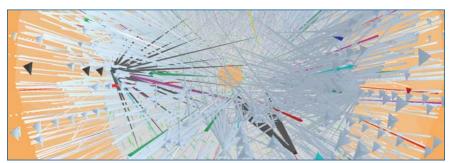
Visualization tools were developed to analyze of the structure and dynamics of ultrascale supercomputing architectures. This analysis created an interactive, immersive visualization of the processing nodes, switching fabric, and message traffic in the 12,000 node ASCI 'Q' Supercomputer for the ASCI Ala Carte project.

Collision detection was added to the Flex Sim commercial simulation package.

The Network Intrusion Detection visualization developed an interactive, immersive visualization of network traffic at the Laboratory's firewall to support exploration, discovery, and analysis of threats to the Laboratory's yellow and green networks.

Numerous division projects depend directly on the development of scripts,







The images above and on the following page are examples of D Division's visualization capabilities. The division's visualization tools have been applied to problems ranging from data flow architecture and traffic simulations to energy interdependencies and potential terrorist activity.

applications, and visualizations using the commercial Geographical Information System suite from ESRI including ArcView and ArcInfo.

Underlying the above projects are a number of ongoing research and development efforts in the following areas: metaphor mapping and reification; composable data flow architectures; information and situational awareness environments; general purpose computation with special purpose graphics processing engines; tele-immersive environments for collaboration; and visualization clusters.

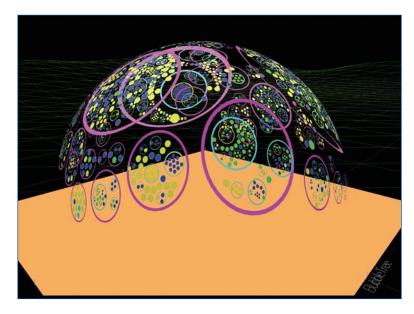
The D Division Visualization Labororatory provides an environment suitable for small group presentations and working sessions in a media-rich environment. A large stereo-capable powerwall with surround sound is the centerpiece. We also have a FakeSpace Laboratories Boom and numerous highperformance graphics systems with flat panel displays and projection systems.

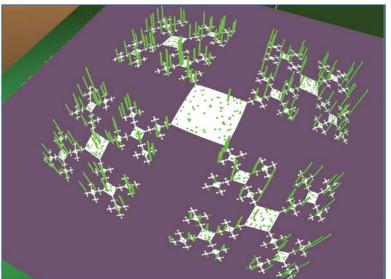
The Visualization Team collaborated with the DoD Joint Virtual Battle Laboratory, Sandia National Laboratory, the ASCI project, UNM's High-Performance Computing Center, George Mason University, FakeSpace Laboratories, Stanford University, University of York, Zyvex Laboratories and internal Laboratory organizations Nonproliferation and International Security (NIS), Center for Integrated Nonotechnologies (CINT), Los Alamos Neutron Science Center (LANSCE), and Laboratory groups CCN-5, CCN-8, and CCS-3 on these projects.

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Decision Support for Critical Infrastructure Protection

ecisions affecting our nation's critical infrastructures are too important to be made without performing an analysis beforehand that carefully weighs the benefits of reducing risks against the cost of protective actions. The most effective way to examine these tradeoffs is to utilize a decision support system that incorporates the results of threat assessments, vulnerability assessments, and analyses that are based on comprehensive, advanced modeling and simulation. Governments (federal, state, local) and industry decision makers can use this type of decision support system to prioritize protection, mitigation, response, and recovery strategies as well as to support emergency response exercises and provide real-time support during crises and emergencies.

The Critical Infrastructure Protection Decision Support System (CIP/DSS) is a joint project undertaken for the U.S. Department of Homeland Security in August 2003 by Argonne National Laboratory, Sandia National Laboratories, and Los Alamos National Laboratory. It provides decision makers with analytical tools for setting priorities to reduce infrastructure vulnerabilities. It will include all major critical infrastructures (electric power, water, telecommunications, food, agriculture, etc.) and key assets (dams, bridges, shopping centers,

etc.) and their primary interdependencies. Activities in subsequent years will improve the integration, resolution, and fidelity of the individual infrastructure models and greatly improve the interdependencies models. It will also incorporate vulnerability and threat data in order to ultimately provide a "risk-based" prioritization decision support system

Examples of issues that this decision support system will be designed to address include the following questions:

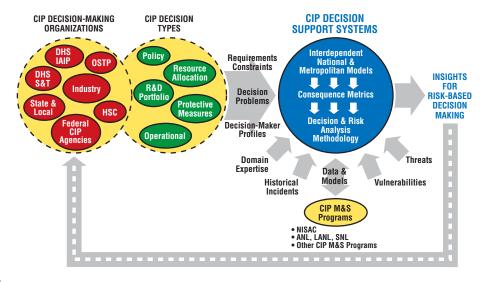
What are the consequences of attacks on our nation's infrastructure in terms of national security, economic impact, public health, and conduct of government, including the consequences to infrastructures?

Are there choke points in our nation's various infrastructures? Where are the areas where one or two attacks could have the largest impact? What are the choke points?

After incorporating consequence, vulnerability, and threat information into an overall risk assessment, what are the highest risk areas?

What investment strategies can the U.S. make that will have the most impact in reducing overall risk?

So far the project has developed systems dynamics models for twelve interdependent urban critical infrastructures, accounting for nearly 1,700 variables,



This type of decision support system can be used to support crisis planning.

and is running these models for a pair of case studies—a widespread telecommunications outage that perturbs numerous other infrastructures, and a livestock pathogen that affects the agriculture, food, and public health sectors. Initial results demonstrate that this model provides insights into the feedback loops between critical infrastructures.

We are collaborating with Lucent Corp.; Booz, Allen, Hamilton; Washington State University; Georgia Tech; and the University of Southern California on this project.

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Radiation Transport

esearchers need to analyze nuclear systems with a state of the art radiation transport code to solve issues in nuclear design, safety, and security.

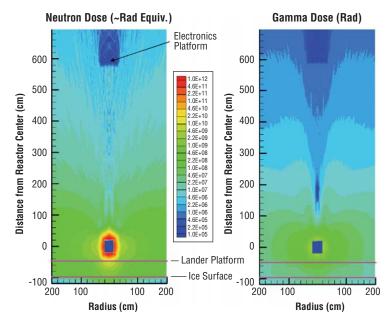
Monte Carlo N-Particle Extended, referred to as MCNPX™ (MCNP extended to all particles and all energies), is an advanced three-dimensional Monte Carlo radiation transport code. It is capable of tracking 34 particle types (including four light ions) over a wide range of energies. The code uses standard evaluated data libraries for proton, neutron, and photonuclear interactions, many extended to 150 MeV, along with physics models when libraries are not available. MCNPX is supported on all UNIX, Linux, and PC platforms, and can be multi-processed with Parallel Virtual Machine (PVM) or Message Passing Interface (MPI).

MCNPX is ideal for a wide variety of problems, particularly in accelerator and space science, and has recently emphasized the importance of looking at charged particles in traditional low-energy problems. The user can now fully track all particles rather than assume their energies are deposited locally upon production. The code offers a choice of either evaluated nuclear data or models, which greatly increases the user's flexibility to investigate problems formerly limited by available data libraries. The code also includes analysis tools com-

monly used in high-energy physics simulations, but little known at lower energies. We are constantly expanding the capabilities of MCNPX to new physics models, new particles such as heavy ions, and unusual energy regions, as well as adding new tallying and variance reduction methods. The addition of a transmutation capability will expand the range of the code in time to track the evolution of the residual nuclei, letting us address critical issues involving the transmutation of waste. Currently our sponsors can use alpha versions, and we are developing transmutation capability in FY04.

Major code applications include the following:

- Shielding design and evaluation for high- and low-energy applications including accelerators, reactors, spacecraft, and cosmic rays;
- Geochemical analysis, for example, the Mars Orbiter data that resulted in the recent verification of water on Mars;
- Dosimetry and health physics calculations;
- Design of reactor and accelerator waste transmuters;
- Standard MCNP criticality capability and reactor design;
- Materials damage analysis (single event effects, bulk damage, etc.);



MCNPX calculation of the dose surrounding the HOMER-15 Mars Polar Lander (15 kWt over 5 years).

- Medical applications including proton, neutron, gamma, and electron therapy;
- Neutron scattering for materials research;
- Neutral and charged particle radiography; and
- Detector design and analysis for threat reduction.

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Space Reactors

pace fission power and propulsion systems could enable numerous exciting space missions. Space fission systems are especially attractive for space missions requiring high power and/or space missions operating in environments where solar power is not readily accessible. Potential missions include ambitious, long-duration missions to the lunar or Martian surface, and NASA's Jupiter Icy Moons Orbiter (JIMO).

Los Alamos began a low-level effort in the mid-1990s to rejuvenate interest in space fission power and propulsion systems. The focus of the Laboratory's approach was on simple, highly testable systems that could enable missions of interest. In 1998, Los Alamos began working closely with NASA to design and fabricate potential space fission power reactor cores (unfueled), with a particular emphasis on testability. In 2000, realistic testing of one such core was initiated, using resistance heaters to closely mimic fission heat deposition. In 2001, the core was coupled to a power conversion subsystem and an ion thruster to provide an end-to-end nuclear electric propulsion breadboard. In 2001, NASA began to express highlevel interest in the development of space fission systems. The D-5-led team continues to perform design, analysis, and testing related to a variety of space reactor concepts and to demonstrate

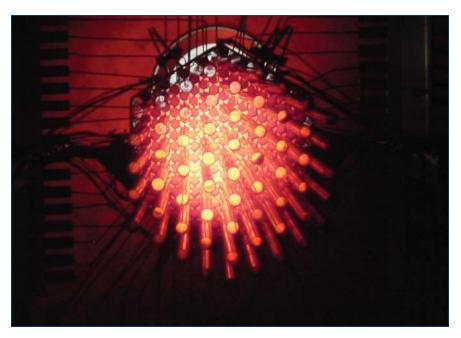
that innovative, highly testable space fission systems can be devised for numerous missions. Los Alamos is currently the reactor design lead for NASA's JIMO Project.

The proposed designs facilitate conversion of paper reactor designs into actual working hardware. Designs emphasize test effectiveness, i.e., the ability to complete highly realistic non-nuclear testing. Systems are designed to be resistant to radiation damage and to have modest fuel burnup requirements, further increasing the worth of realistic non-nuclear testing. Numerous hardware tests have been performed to confirm the potential performance of the proposed systems. A JIMO-class reactor is shown here.

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SAFF-100 Core Simulator Test

Thermal-Hydraulic System Code Development and Applications

ontinuing to ensure the safety of nuclear power plants and other nuclear reactor facilities, D-5 develops and applies best-estimate thermal-hydraulics system analysis codes.

Independent safety analyses are performed using best-estimate thermalhydraulic codes to assess reactor safety. The TRAC/RELAP Advanced Computational Engine (TRACE) code being developed by Los Alamos and other institutions for the NRC has been used to model nuclear power plants and simulate postulated accident scenarios to show that the power plant safety systems can bring the plant to safe shutdown conditions.

The TRACE (formerly Transient Reactor Analysis Code) thermal-hydraulic system code has been under continuous development by Los Alamos for the NRC since 1970. The TRACE code continues to evolve with increasing understanding of complex two-phase, multicomponent fluid phenomenology. After sponsoring multiple codes for over two decades, the NRC has selected TRACE as the sole platform for future development. The Laboratory plays a key role in an ambitious multi-institutional development program designed to modernize and expand the existing code capabilities.

As the NRC considers pre-application review of new reactor concepts such as the Pebble Bed Modular Reactor (PBMR) and the Simplified Boiling Water Reactor, the Laboratory has been in a position to provide the needed developmental and analysis support.

In support of the Accelerator Transmutation of Waste program, TRACE has been updated to include liquid-metal fluid properties and to enable the tracking of trace species. A TRACE model of the Los Alamos Development of Leadalloy Target Applications (DELTA) loop facility, a liquid lead-bismuth materials test loop, has been developed and used to simulate actual test runs.

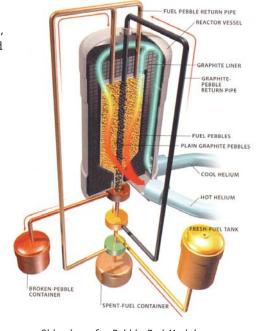
Recent TRACE code development tasks have sought to provide new Pebble-Bed core materials and component models as well as to revise channel modeling for the simplified boiling water reactor. Enhancements have included threedimensional fuel sphere-coolant heat transfer capabilities for the PMBR and modeling capabilities for the water rods and partial-length fuel rods associated with the Enhanced Simplified Boiling Water Reactor (ESBWR) fuel designs. Additional implicit heat structure development support for KAPL will reduce run times on key design basis accident analyses. In the future, we look toward

developmental tasks in support of the GEN-IV reactor concepts as well as the potential for hybrid code development, coupling TRACE to computational fluid dynamic (CFD) and/or reactor physics analysis kernels.

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Side view of a Pebble Bed Modular Reactor (Courtesy of Technology Review, Illustration: Slim Films, Source: Exelor)

Nuclear Weapons Surety Modeling

uclear weapons safety issues are an ever-present concern at the Laboratory. D-5 has developed an effective approach to systematically identify and evaluate risks for any of these issues.

We use formal logic models, called scenario possibility trees, to identify accident scenarios. They are designed for problems involving complex, poorly understood phenomena, and provide a knowledge base structure as well as a framework for expert opinion. Simplified physical models are used to screen identified scenarios. These scoping tools are coordinated with possibility tree solutions (accident paths). Scoping tools model the most important physical processes associated with nuclear weapons safety and must be flexible in response to each proposed physical phenomenon. A good scooping tool guides and focuses development of more detailed models and experiments of weapons phenomena that drive risk.

Fault trees are a type of formal logic models that have been used for years in the aircraft, nuclear reactor, and other industries. Our possibility trees are related in that they also use deductive logic and the gates have mathematical equivalents, but they represent the details of physical processes such as heat transfer, rather than events such as pump failure. The solutions of possibility

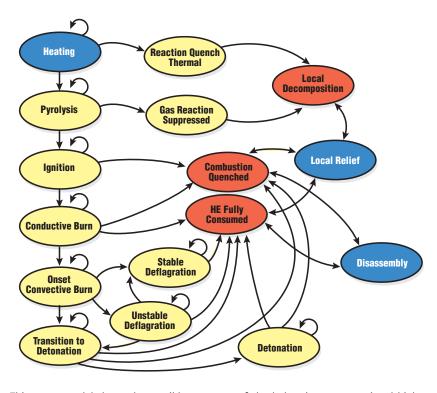
trees for safety issues are individual accident paths.

Possibility trees have evolved at the Laboratory out of the need to deal with complex, poorly understood weapons phenomena. They can represent the entire weapons safety knowledge base: experiment results, expert opinion, and model calculations within the same framework. When speculative information is all that is available, alternative views are easily represented.

The solution of possibility trees for complex phenomena often yields a large number of accident paths. Researchers need a means to screen this large number of paths. Screening the results is not as much a nuisance as might be supposed. We have often discovered heretofore unknown, but important, paths by examining a solution set. Some of these have been termed the "unknown unknowns" in other approaches.

We screened using scoping tools that are focused on a particular subset of the possibility tree solution paths. We create these by using the knowledge base to identify the most important physical processes, enough to give approximate solutions to boundary conditions. We improve and confirm our models with other, more detailed models and experiments when these are available.

Practically any accident scenario with interesting consequences is a valid ap-



This surety model shows the possible outcomes of slowly heating a conventional high explosive (HE).

plication of our surety modeling approach. In the diagram, we focus on cook-off of high explosives.

We have developed two possibility trees for cook-off. One shows the possible outcomes of slowly heating a conventional high explosive. Another shows possible sequences of physical processes that could lead to a violent outcome.

As the above diagram shows, a widely varying set of outcome states is possible, ranging from a thermal quench that produces only mild damage to the explosive up through a detonation that efficiently releases the chemical energy contained in the explosive. In general, loops like those seen on some of the graph nodes above refer to cyclic subprocesses that

occur within the context of the node. The loops shown here refer to reaction spreading processes. These serve to inhibit reaction locally and delay thermal explosion at a given location. Meanwhile, a larger volume of the surrounding explosive has enough time to become primed for explosion. In the absence of reaction spreading, a relatively small volume of explosive might be involved in an energy-releasing reaction. Reaction spreading leads to a larger fraction of explosive becoming involved and can therefore lead to more violent outcomes. This phenomenon plays an important role in determining the level of cook-off violence and was discovered with the aid of the process trees we developed.

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Assessing Vulnerability and Consequences

os Alamos has been working with the DOE, NRC, and Sandia National Laboratories to develop a robust methodology to analyze the threats to nuclear installations in the wake of the attacks on 9/11. This work has led D-5 to a set of capabilities and tools that allow for a flexible approach to analyzing vulnerabilities based upon the threat to a facility. Los Alamos is capable of providing the following information in support of vulnerability assessments:

- ▼ Identify threats
- Identify targets
- ▼ Identify possible attack scenarios
- Examine likelihood of scenarios
- Determine consequences
- Evaluate protection
- Analyze for improvements

The technology and experience used to assess postulated nuclear facility accidents and their consequences can also be used to assess postulated nuclear attack scenarios. These technologies include probablistic risk assessment, interior aerosol transport modeling, and atmospheric dispersion modeling.

Probabilistic Risk Assessment

(PRA). Los Alamos uses risk as a metric for comparing different attack scenarios. Risk requires some estimate of the probability that different scenarios are attempted and the conditional probability of a range of consequences given the attempt. The Laboratory's primarily uses the Logic Evolved Decision (LED) tool to evaluate risk. The LED approach uses logic models and approximate reasoning (AR) to produce rigorous estimates of attempt probability using qualitative and subjective inputs. Instead of asking an expert to make a direct estimate of attempt probability for each member of a set of scenarios, the expert's evaluation process is used to determine which attack scenarios are most attractive to different classes of terrorists. Then the values of the factors used in estimating the attractiveness for each scenario are collected, and the evaluation process is used on each scenario to consistently and systematically produce an attractiveness ranking of the scenarios.

Interior Aerosol Transport

Modeling. Los Alamos uses many tools and methods to estimate the transport of aerosol particles through buildings and ductwork to the environment for postulated accident scenarios. These tools range from simple hand calculations to complex three-dimensional flow codes. Calculating aerosol transport in buildings is fundamental to most nuclear safety issues.

Atmospheric Dispersion Modeling.

Atmospheric dispersion is the key transport mechanism for the release of most hazardous materials, most importantly nuclear materials. To evaluate this trans-

port mechanism, D-5 utilizes industry standard and in-house tools to evaluate the atmospheric dispersion.

We can model the spectrum of distances typically of concern in far-field atmospheric dispersion where simple Gaussian models are employed to near-field atmospheric dispersions that require complex three-dimensional flow fields be solved in order to accurately capture the concentration of aerosols.

Some of the primary tools for atmospheric dispersion modeling include the Laboratory-modified INPUFF code, the QWIC-URB code, and the Laboratory's HIGRAD code. The INPUFF code takes a far-field approach, utilizing a simple Gaussian puff model for computational efficiency. At the other extreme, the HIGRAD model uses a large-eddy CFD approach to resolve three-dimensional flow field effects with close to real meteorology (near-field atmospheric dispersion). As an intermediate approach, the QWIC-URB model expands on the Gaussian approach by employing empirically based, multidimensional effects in the building wake regions. This intermediate approach yields improved accuracy over the far-field approach without the computational penalty associated with a full CFD analysis.

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